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Soil Erosion and Sediment Delivery in the Blue Creek Watershed, Pike County, Illinois Preliminary Analysis

Illinois State Environmental Protection Agency
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SOIL EROSION AND SEDIMENT DELIVERY IN THE BLUE CREEK WATERSHED

Pike County, Illinois

Illinois Environmental Protection Agency
Division of Water Pollution Control
2200 Churchill Road
Springfield, Illinois 62706

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Soil Erosion and Sediment Delivery In the Blue Creek Watershed Pike County, Illinois

Preliminary Analysis

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May, 1982

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Executive Summary

1. Background: The Illinois Environmental Protection Agency (IEPA) in cooperation with the United States Department of Agriculture Agencies, Agricultural Stabilization and Conservation Service (ASCS) and the Soil Conservation Service (SCS), is evaluating the impact of Resource Management Systems (RMS's) implemented under the Agricultural Conservation Program (ACP) Special Water Quality Project in the Blue Creek Watershed, Pike County, Illinois. The primary objective of this project is to identify the most viable agricultural non-point source (NPS) control strategy, demonstrate its effectiveness, and develop a methodology to identify land causing water quality problems and to determine the appropriate RMS's.

2. Investigation: Adequate control of agricultural non-point source pollution requires an effective and efficient management program. An integral component of this is the identification of those areas which act as sources of non-point source pollution. Specific areas that contribute to non-point source pollution must be identified in order to direct programs and practices to correct the problem areas. This study integrates the results of a SCS Phase II Erosion Inventory, a computerized geo-based generated potential gross erosion inventory (ADAPT) and a lake sedimentation survey. The goal was to determine a sediment delivery ratio in an attempt to identify sediment source areas.

3. Systems: The gully and streambank erosion inventory system utilized was the standard SCS Phase II Erosion Inventory Method. The field inventory was performed by IEPA personnel. The ADAPT (Areal Design and Planning Tool) is a geo-based computer mapping and planning system. This computerized system generated potential gross (sheet and rill) erosion for specific land use/cover designations. Land use/cover was delineated by individual farm-field boundaries. The existing land management activities were delineated by SCS and IEPA personnel. For each field in row crop rotation, the existing cropland management practices were defined.

   A Sedimentation survey was conducted on Pittsfield City Lake in 1979 by the Illinois State Water Survey. Sounding data from 16 cross sections were collected in the 1979 survey.

4. Conclusions: This study concluded that the gross erosion for the Blue Creek Watershed is 63,313 tons (62,867 tons by sheet & rill erosion and 446 tons by gully erosion. This erosion data was correlated with lake sedimentation data from Pittsfield lake in order to determine the sediment delivery ratio. This ratio was calculated to be 66%.

   Currently, 1.08% per year of lake capacity is lost to sedimentation. Under these conditions the lake will be completely filled in 92 years. Under "attainable" management conditions, the life of the lake would gain 51 years and under "ultimate" conditions the life of the lake would be extended by 130 years.

Soil Erosion and Sediment Delivery
in the Blue Creek Watershed

Introduction

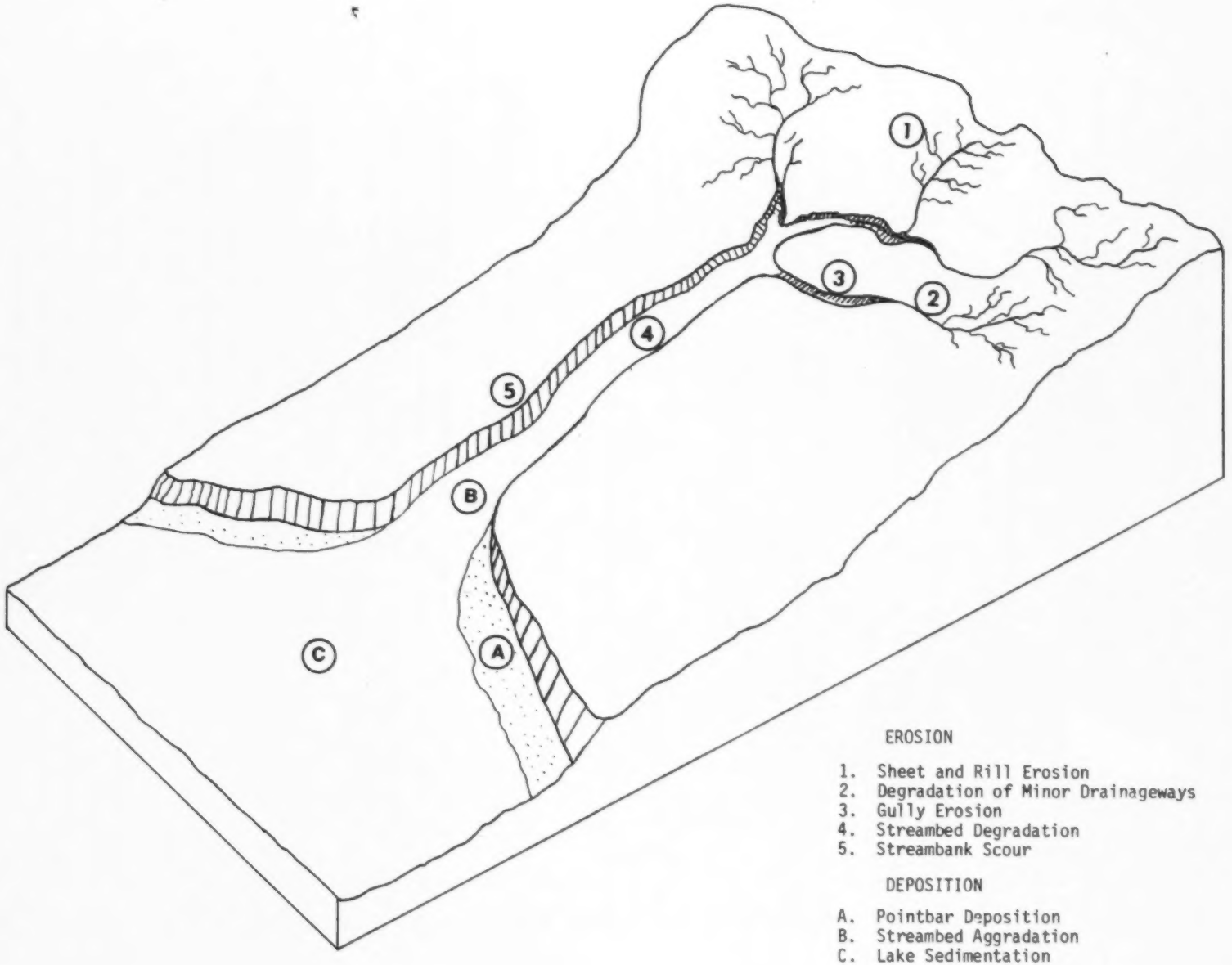
Agriculture is the most widespread nonpoint source of water pollution across the nation. Initial "208" planning efforts documented that agricultural activities are a major source of pollution in Illinois and mandated the development of plans to control this nonpoint source pollution from agriculture. The most severe agricultural related problem is soil erosion resulting in sedimentation. Nationwide, approximately half of the total sediment delivered to lakes and streams is from cropland. In Illinois estimated gross erosion exceeds 180 million tons annually, with 158 million tons from sheet and rill erosion from cropland (IEPA, 1979).

Erosion is defined as the detachment and movement of soil or rock fragments by water, wind, ice or gravity. There are five principal types of water erosion: 1) gully; 2) natural; 3) rill; 4) sheet; and 5) splash erosion. Three types of water erosion were measured in this study: sheet, rill and gully (Figure 1). For this study, the term erosion refers only to those three.

Soil erosion has several major consequences: 1) the original sites of the eroded material are degraded, therefore potential productivity is lessened; 2) the sites of deposition of the soil particles are altered physically, chemically and hydrologically, and 3) the chemical and physical nature of the transporting water system is drastically affected. Economic values related to these three major consequences are difficult to assess. Degradation of the productive capacity of agricultural land results in depletions of yield. However, the most serious problem with erosion is the deteriorating off-site effect it has on the aquatic environment. Runoff from agricultural land can carry soil particles, nutrients, pesticides, fertilizers, livestock wastes and other pollutants to the receiving water. This runoff, carrying large amounts of suspended soil particles scours the stream channel, alters the character of the stream, and affects aquatic life by impairing functions such as photosynthesis, respiration, growth and reproduction.

Sediment is defined as solid materials which have been transported from their place of origin by erosion. It can be either in suspension or have been deposited. Sediment is a significant pollutant because of its physical properties, potential chemical interactions and total loads. Suspended solids carries pollutants such as pesticides, nutrients and trace metals, causing water quality problems. Suspended solids chemically and physically deteriorate water quality, resulting in reduced use. The settling of suspended solids reduces the storage and flow capacities of our streams, lakes and reservoirs, adversely affecting water supplies and increasing flood potential. Estimates indicate that 8,000 acre feet of storage capacity are lost each year in the State's impoundments (IEPA, 1979).

Figure 1. Erosion and Deposition Occurrence Diagram.



The only universal method of controlling agricultural nonpoint source pollution is by implementing various practices that control nonpoint pollution at its source. Specific areas that contribute to erosion must be identified in order to direct programs and practices to correct the problem areas.

This study integrates the results of a SCS Phase II Erosion Inventory, a computerized geo-based generated potential gross erosion inventory (ADAPT), and a lake sedimentation survey to calculate a sediment delivery ratio.

Control of Soil Erosion

The soil erosion process is accelerated by man's activities or natural catastrophies, causing soil loss rates to escalate. Agricultural management activities can also cause higher rate of erosion by disturbing the normal vegetation cover.

The basic soil erosion process converts the energy source from the momentum of raindrop impact to work in the form of detachment and transport of soil particles. Detached soil particles are flushed into surface soil pores, thus plugging soil pores and reducing soil infiltration capacity. Reduced infiltration results in higher quantities of overland flow at which point the energy for transportation of soil particles can be related to the kinetic energy of the moving water. The greatest deterrent to surface soil erosion is an adequate crop cover. An adequate plant cover absorbs the energy of raindrop impact thus preventing detachment and transport of soil particles. Stems and roots reduce the velocity of overland flow, thus infiltration rates are maintained at a much higher rate when there is an active plant cover. Annual additions of plant litter protect the soil surface and improve soil properties as organic residue increases the stability of aggregates and thus resistance to increasing erosion processes.

It is logical that those land management methods which expose maximum amounts of bare soil will have the larger amounts of soil loss. Agricultural land management which incorporates conservation tillage, contour planting and other best management practices has been effective in reducing soil loss.

The only feasible method of controlling this erosion is by implementing various conservation practices which lower soil loss rates. Resource Management Systems (RMS) can be implemented by the individual land owner/operator that would reduce soil erosion to more tolerable losses. Reducing soil erosion on the individual land management units should reduce off-site damages associated with soil loss from agricultural practices.

RMS's can be divided into two groups. The first, cultural practices, are nonstructural in nature. This group includes no-till, conservation tillage, contouring and stripcropping. The second group consists of structural practices which usually require off-farm equipment for construction. The practices in this group include terraces, diversions, grassed waterways, lagoons and filter strips.

The basic principle of the above RMS's are to alter the runoff, provide cover for soil or change the water absorption capacity of soil, rain splash energy, and soil structure. Most RMS's are designed to control either, 1) detachment and transport, or 2) only transport of soil particles.

Economically, the two classes of practices can be distinguished on the basis of both initial and recurring cost. Structural practices are characterized by a relatively high initial cost and lower annual costs, representing the cost of maintenance. Cultural practices, such as the alteration of a tillage system or removal of land from production for some purpose, have a recurring annual cost based on the value of production lost through the application of the practice. These costs in agricultural situations are dependent on the costs of inputs to farm production and the value of the farm products to be sold (Lake, 1977).

Presently, the United States Department of Agriculture and the Illinois Department of Agriculture offer technical and/or financial assistance to land owner/operators for the implementation of RMS's. However, the implementation of RMS's is strictly voluntary on the land owner/operators part. Even with assistance available from various agencies, the deciding factor is the willingness of the land owner/operator to implement conservation practices.

Blue Creek Watershed Project

The Blue Creek Watershed in Pike County, Illinois was selected to demonstrate the effects of erosion control practices upon water quality. The project area was designated an Agricultural Conservation Program (ACP) Special Water Quality Project Area, which provides financial assistance to land owners/operators for the implementation of conservation and pollution control practices. The Illinois Environmental Protection Agency (IEPA) in cooperation with United States Department of Agricultural Agencies, Agricultural Stablization and Conservation Service (ASCS) and Soil Conservation Service (SCS), is evaluating the impact RMS's implemented under the the ACP Special Water Quality Project in the Blue Creek Watershed.

The monitoring and evaluation project's primary purposes are to assess gross erosion, determine the actual yield of pollutants from different agricultural practices to downstream receiving water and to examine their effect on quality and use of the water resources. Monitoring and evaluating of RMS's will document actual impacts from agricultural practices and aid in determining strategies for the implementation of the State Soil Erosion and Water Quality Program. This study will provide a comparison of cause/effect relationships between various agricultural practices and water quality impacts and an evaluation between high and low cost strategies. The most viable agricultural non-point source control strategy will be developed and its effectiveness evaluated.

Study Area

The Blue Creek Watershed encompasses approximately 7,012 acres (11 square miles) in east central Pike County, Illinois. (Figure 2) Terrain is hilly, relative to most areas in Illinois and has a high soil loss potential due to its steep slopes, fine grained soils and agricultural land use practices. (Fig. 3, Table 1) The Blue Creek Watershed drains into Pittsfield City Lake, which was constructed in 1961 as a multiple purpose resevoir. Average annual soil loss is estimated at 8.1 tons/acre/year (IEPA, 1979). Erosion from livestock operations (primarily hogs) contributes to the total basin sediment load. For a detailed description of the Blue Creek Watershed and the monitoring program refer to "Blue Creek Watershed Project Pike County, Illinois, May 1977 - October 1980" (Davenport, 1981).

Figure 2: Blue Creek Watershed, Pike County, Illinois

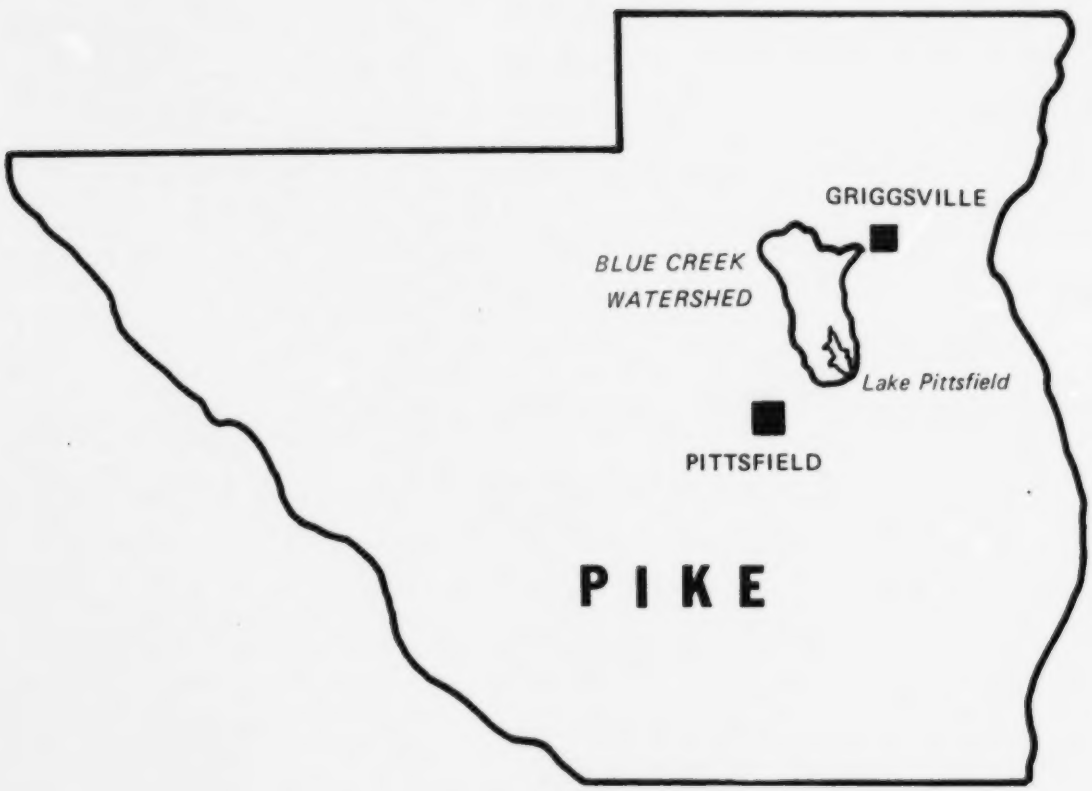
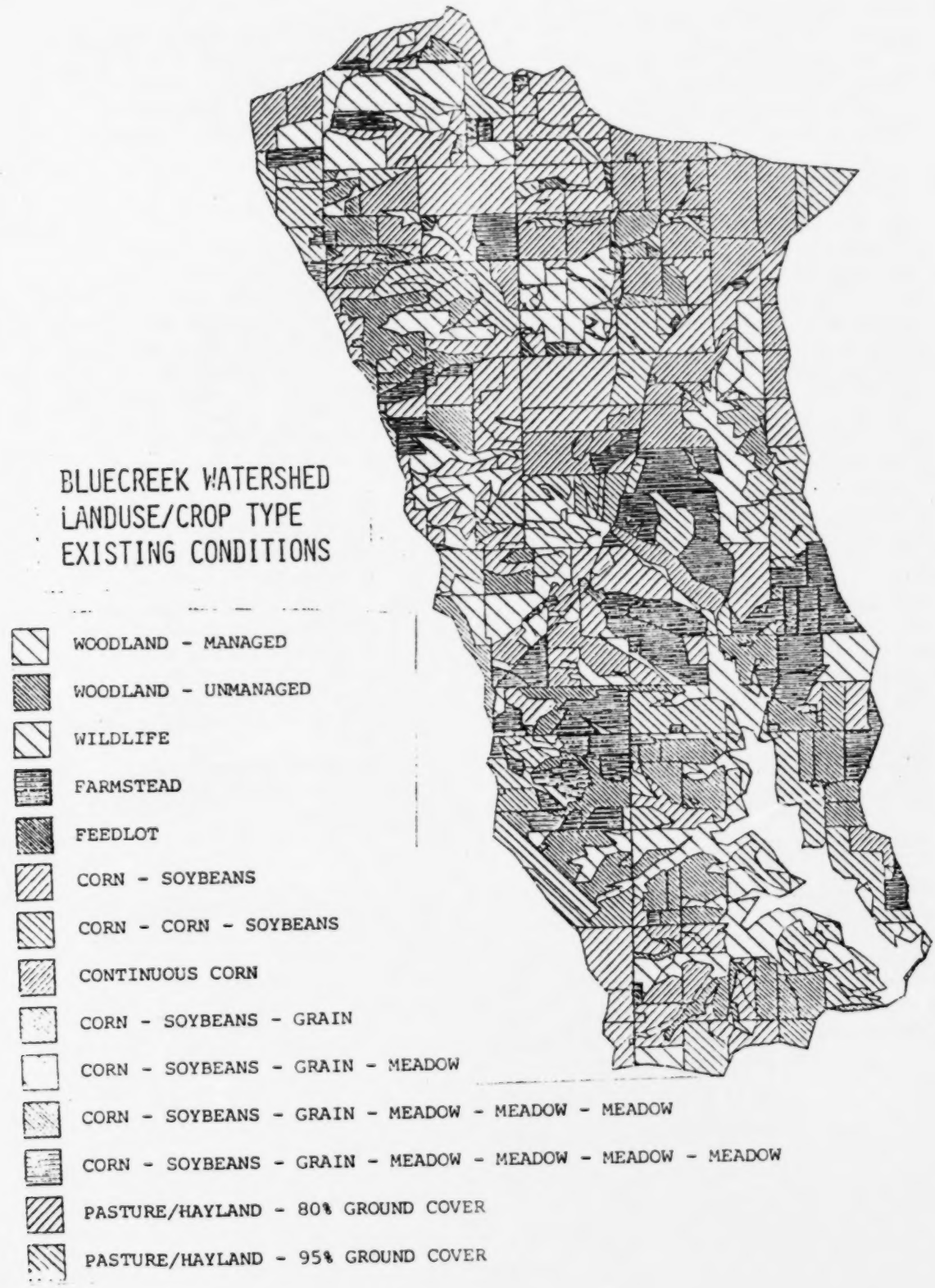


Table 1. Land use/cover in the Blue Creek, Watershed, 1981 by acres and percent (Davenport, 1982)

Land Cover Category	No. of Acres	Percent
Cropland	3960.8	56.4
Pasture/Hayland	1519.3	21.6
Woodlands	810.0	11.6
Water/Wetland	236.4	3.5
Wildlife	311.7	4.4
Farmstead	109.1	1.6
Feedlot	65.5	0.9
	7012.8	100

Figure 3: Existing Land Use/Cover Conditions as of October 1, 1980


BLUECREEK WATERSHED
LANDUSE/CROP TYPE
EXISTING CONDITIONS
WOODLAND - MANAGED
WOODLAND - UNMANAGED
WILDLIFE
FARMSTEAD
FEEDLOT
CORN - SOYBEANS
CORN - CORN - SOYBEANS
CONTINUOUS CORN
CORN - SOYBEANS - GRAIN
CORN - SOYBEANS - GRAIN - MEADOW
CORN - SOYBEANS - GRAIN - MEADOW - MEADOW - MEADOW
CORN - SOYBEANS - GRAIN - MEADOW - MEADOW - MEADOW - MEADOW
PASTURE/HAYLAND - 80% GROUND COVER
PASTURE/HAYLAND - 95% GROUND COVER

Methods and Procedures

A field method (gully and stream bank) and a computerized method (sheet and rill) were used to determine the potential gross erosion in the Blue Creek Watershed. The field method consisted of applying a standard SCS Phase II Erosion Inventory to the watershed. The computerized method (ADAPT) generated potential gross erosion for specified land use/cover designations.

Field Method

The SCS Phase II Erosion Inventory manual procedure was utilized for collecting data on streambank and gully erosion within the watershed. The watershed was divided into sampling units. Within each sampling unit, two sets of data were collected. Section I of the worksheet (example in Appendix) contained streambank information and data on eroding gullies, ditches, and canals that are not on roadsides or construction sites. General information was noted for all bank segments within each sampling unit, such as the type of channel, general setting and length of the bank segment. For those bank segments where erosion was occurring a direct volume method was used to calculate the annual tons of erosion.

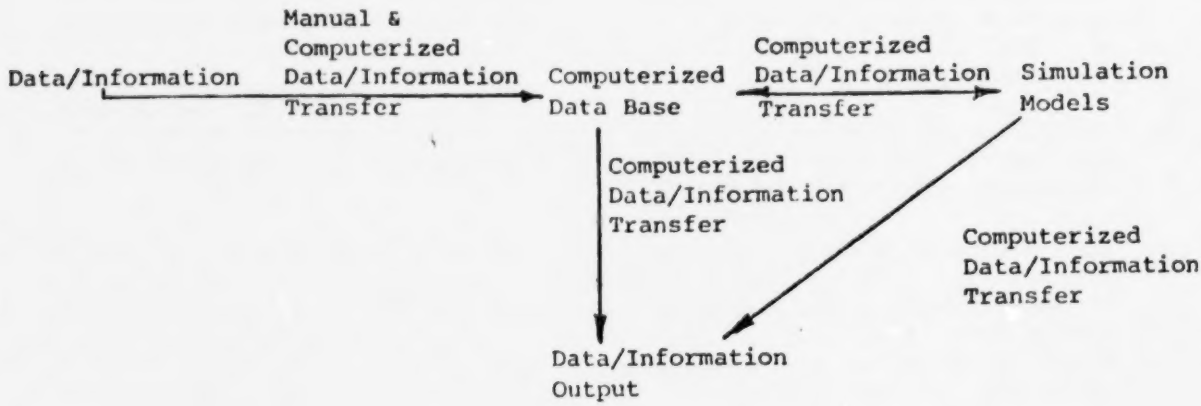
Section II of the worksheet provided for the collection of data for erosion on construction sites, roads, and roadsides. Areas disturbed by construction activity are defined in the Erosion Inventory Instruction Sheet as "land areas void of vegetation at the time of observation, where man has modified the land surface by cutting or filling for construction of roads, buildings, reservoirs, and similar activities. Strip mines, gravel pits, and other extrative activities are not to be considered construction sites". In Section II either the direct volume method or the Universal Soil Loss Equation could be utilized in calculating erosion.

The field data inventory was performed by Environmental Protection Specialist, Rodney Mutz (IEPA). A more detailed description of the SCS Phase II Erosion Inventory is in the Appendix Section.

Computerized Method

ADAPT (Areal Design and Planning Tool), a geo-based computer mapping and planning system, was utilized for determining potential gross erosion on the Blue Creek Watershed. This computer modeling system represents a synthesis of two popular computer based approaches to analysis and planning: 1) spatial/geographical data base; and 2) analytical mathematical modeling techniques. The ADAPT system is a proprietary system owned by W.E. Gates and Associates, Inc., of Batavia, Ohio.

The basic modules of ADAPT are:



The data/information incorporated into the data base is determined by the needs of a particular ADAPT application. A combination of manual and computer based techniques are used to capture the data/information and transfer it to the computerized data base.

The ADAPT Non-Point Source Screening Model was utilized to estimate the potential gross erosion conditions associated with different land management activities. This model is based on the Universal Soil Loss Equation (USLE), which is an accepted method for estimating the average annual sheet and rill erosion in tons per acre. Many factors affect the erosion rate and are incorporated into the equation: $A = RLSKCP$.

A = soil erosion loss
R = rainfall
LS = length and steepness of slope
K = soil erodibility
C = cover and crop management
P = conservation practices

IEPA in cooperation with the Illinois State Water Survey and SCS field personnel verified the ADAPT Non-Point Source Screening Model in the Blue Creek Watershed. In this study the results of a Standard SCS Phase 1 Land Resource Inventory were compared to those of the computerized geo-based generated potential gross erosion inventory. The study concluded that ADAPT provided a means for quantifying potential gross erosion as accurately as the traditional field method. For a more detailed description of this study refer to "Comparative Evaluation of Gross Erosion Assessment Techniques used in the Blue Creek Watershed, Pike County, Illinois" (Davenport, 1982).

USGS, 7/1/2 minute maps provided the topographical and political boundaries; soil series data was provided by SCS. Land use/cover in fourteen categories was furnished by IEPA and SCS from aerial photos and ground surveys. USLE factors, cropping (C) and conservation practice (P) were representative numbers provided by the local District Conservationist of the SCS. The slope length factor, also obtained from SCS, was a representative slope length for each soil series. The percent slope was calculated by the ADAPT System. The soil erodibility factor and the rainfall factor were obtained from Resource Conservation Planning Technical Note - IL-4 (USDA-SCS, 1977).

Land use/cover was delineated by individual farm-field boundaries. The present land management activities were delineated by the local District Conservationist, Wayne Kinney and Environmental Protection Specialist, Rodney Mutz (IEPA). For each field in row crop rotation, the existing cropland management practices were defined. A list of the crop rotations, tillage systems, and conservation practices making up these management practices for the fields in the watershed is presented in the Appendix Section. The range of cell size was from .06 to 8.19 acres (average = .88 acre) for the completed field level data base.

Sedimentation Survey

A sediment survey was conducted on Pittsfield City Lake in 1979 by the Illinois State Water Survey. Sounding data from 16 cross sections were collected in the 1979 survey. Figure 4 shows the locations of the lake cross sections.

In the 1979 survey, sounding data was collected at 25 or 50 foot intervals on each cross section to measure both the original (1961) and current (1979) depths of water in the lake at the spillway elevation. All depth measurements were made with a 2-inch diameter aluminum pole marked in tenths of feet. The pole was first lowered till it touched the current lake bottom and a depth measurement was made. The pole was then pushed through the accumulated sediment until it hit the solid original lake bed where another depth measurement was made (Bogner, 1979).

Sediment Delivery Ratio

The soil erosion inventories were used to compute total soil loss. The USLE or the direct volume method was used to calculate the soil loss rate in tons per acre per year. The total amount of potential gross erosion is the combination of the potential gross erosion estimates of the Phase II Inventory and the ADAPT system. The average erosion rate is defined as the amount of gross erosion per year divided by the acreage.

The rate at which sediment is being deposited in a lake is determined by measuring the amount of sediment and dividing by the age of the lake. The Brune trap efficiency curve is utilized to determine the trap efficiency of the reservoir which gives the relationship of the sediment accumulation in the lake to that carried on downstream. Bogner (1979) estimated the trap efficiency to be 93%, using standard techniques. From this, the sediment yield is calculated (tons of sediment delivered to the reservoir/year). Finally, the sediment delivery ratio can be determined. This is defined as the ratio of sediment yield to the amount of gross erosion.

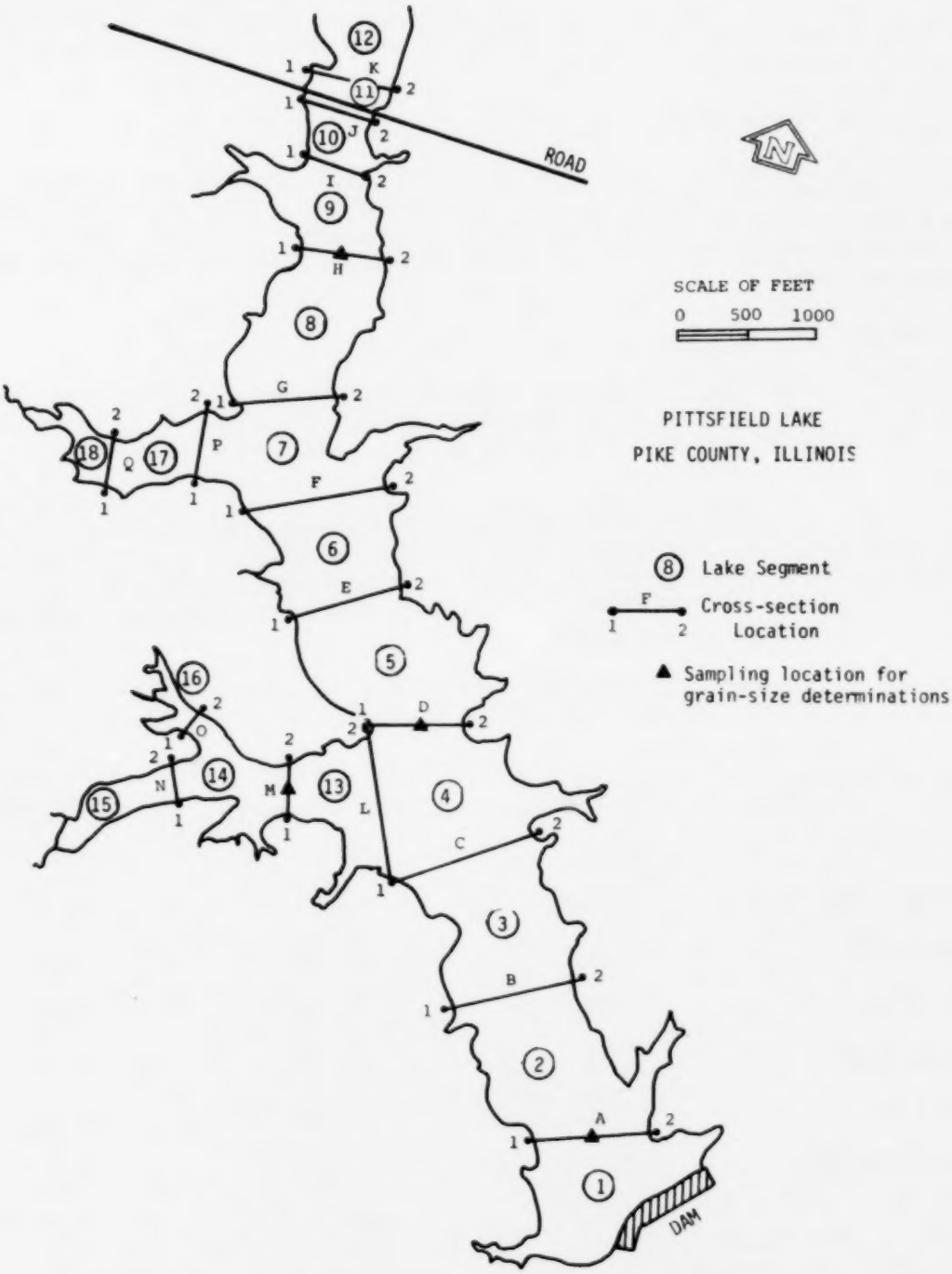


Figure 4. Locations of Range Stations and Segments for 1979 Sedimentation Survey

*Courtesy of ISWS

Results

Results from the SCS Phase II Erosion (gully and streambank) Inventory are given below. The ADAPT system estimates are summarized in Tables 2. Figure 5 spatially locates the potential sheet and rill erosion by soil loss category on the watershed.

Gully and Streambank Erosion

Gully and streambank erosion for the 7,012 acre watershed was estimated to be 446 tons per year. Erosion on construction sites, roads, roadsides and channel bottoms was negligible, so it was not considered. Total erosion estimated using the SCS Phase II Erosion Inventory method was 446 tons per year.

Sheet and Rill Erosion

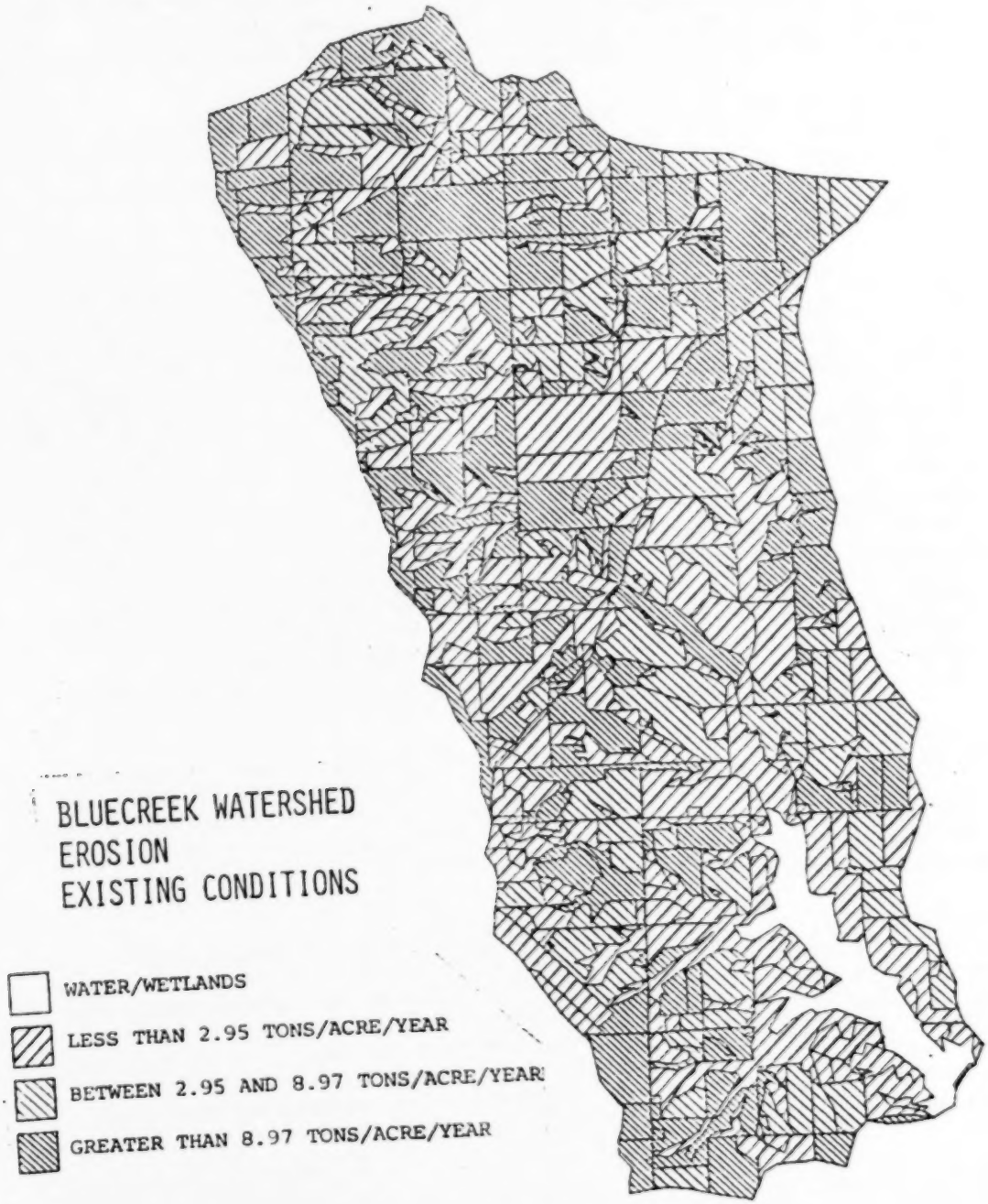
Potential sheet and rill erosion rates by land use/cover category for the watershed as determined using the ADAPT system, are summarized in Table 2. The average erosion under the specified present conditions totaled 62,867 tons.

The average erosion rates ranged from 14.1 tons/acre for cropland to 0.4 tons/acre for wildlife areas. Only cropland and feedlot areas had an annual average erosion over 10 tons/acre, these were 14.1 and 35.5 tons respectively. The remaining land use/cover categories had annual average soil losses under 10 tons/acre.

Table 2. Potential gross erosion rates by land use/cover category on the Blue Creek Watershed as determined by the ADAPT system (Daveport, 1982).

Land Use/Cover	# of Acres	Total Erosion (Tons)	Erosion Rate (Tons/Acre/year)
Cropland	3960.8	55994.7	14.1
Pasture/Hayland	1519.3	1640.1	1.1
Woodland	810.0	2674.0	3.3
Wildlife	311.7	116.5	0.4
Farmstead	109.1	118.3	1.1
Feedlot	65.5	2323.4	35.5
Water/Wetland	236.4	0.0	0.0
	7012.8	62867	9.0

Figure 5. Location and Severity of Potential Soil Erosion In The Blue Creek Watershed, as Determined Using the ADAPT System.



Sedimentation Survey

The sounding data from the 1979 survey was used to calculate the 1961 and 1979 storage capacities of the lake at the spillway level. The difference between these storage capacities is the lake volume that was lost to sedimentation since 1961. The data showed that Pittsfield City Lake has lost 19.7% of its original capacity as a result of sedimentation between 1961 and 1979 (1.08% per year).

The total weight of sediment within the lake was calculated to be 706,600 tons (Bogner, 1979). The average annual sediment deposition in the lake for the past 18.3 years (1961-1979) was calculated to be 38,612 tons.

Discussion

In this study, the total amount of gross erosion was estimated on the watershed. Gross erosion computations by the soil loss equation and direct volume method did not include channel-type erosion; this is being computed separately and is not included in this analysis. The stream geometry and channel characteristics monitoring consist of two parts: 1) monitoring channel dynamics; and 2) analyzing particle size distribution of bed material at certain stream location after rainfall events. The cross section were measured in 1979 and 1980 to show changes in the stream cross section due to deposition and scouring. The monitoring of channel dynamics consisted of determining cross sectional area of the channel at 51 locations, 40 locations were on Blue Creek and 11 were on a tributary to Blue Creek. Determining deposition and scouring in the channel at 51 locations combined with the particle size distribution analyses of bed material at five sites in the channel will enable the contribution of bed material to the total suspended load to be estimated. The results of this monitoring will be incorporated into the final report on soil erosion and sediment delivery.

Potential gross erosion for the Blue Creek Watershed Basin is estimated to be 63,313 tons/year sheet and rill erosion contributes 62,867 tons yearly, over 99% of the total. Gully and streambank erosion contributes less than 1%, this is a result of the low drainage density network and the lack construction sites, and low density of roads and roadsides within the watershed.

Soil particles are often detached and transported for only a short distance in any one storm but may ultimately reach the watercourse after repeated storms. Moore et al (1977) referred to this phenomena as the "play fairs" law, implying that sooner or later sediment deposited in concentrated flow channels will reach streams or lakes. Trimble (1975) has reported that sediment deposited in stream channels will move downstream as upstream loading decreases. The location of monitoring stations on Blue Creek should enable confirmation of this process (Figure 6).

The source area of runoff in a watershed expands and contracts according to rainfall rates and the capacity of the soil to retain and release waters (Dunne, 1978). This variable source concept has important implications for the understanding of sediment source areas because it

provides a model explaining how a channel network grows to many times its average perennial dimensions during storm runoff as streams become both longer and wider, thus allowing a larger area to contribute to the total basin sediment yield than during baseflow periods. The variable source concept applies to Blue Creek Watershed because infiltration is not a limiting factor. If surface runoff is generated from a small portion of the watershed close to the channel network or lake, the area of significance for sediment yield will be limited to this contributing area. This concept is referred to as the "partial area" theory. Thus, all lands are to considered to contribute or yield proportionate shares.

Distance of travel is important due to settling relationships between streams carrying capacity and total suspended load. The parameters which influence this sediment yield, and therefore the sediment delivery ratio, are: the size of the drainage area, the number of the stream channels (stream density), the gradient of the stream channels, the size and density of the sediment particles, the stream channel roughness and the soil, topographic and weather parameters that control the magnitude and duration of stream flow. The stream network cannot be viewed as a static force. The acceptance of the dynamic character of both soil erodibility, erosion processes, of the contributing area and stream channel networks within the watershed necessarily means sediment entrainment is very time and event variant (Walling, 1977).

The relative efficiency of the various erosion processes upon yield to the lake varies by season and location within the watershed. The sediment delivery ratio for each process was not calculated or estimated. The delivery ratios may differ significantly for the sediments from the two types of sources (gully and streambank/sheet and rill). Channel erosion produces sediment that is immediately available to the transport system, much of it tends to remain in motion as bedload and suspended sediment. The partial area and variable source area concepts pertaining to storm runoff production have very important implications for sediment source areas and erosion processes. A substantial reduction in the amount of sediment delivered to a stream may result in a compensatory increase in channel erosion. However, the composition of sediment derived from channel erosion will usually differ substantially from that derived from sheet and rill erosion from cropland. The particle size analysis component of the stream geometry and channel characteristic monitoring will enable detection of this phenomenon if it should occur. Most of the sediment transported by streamflow is carried during a few large storm events. Figure 6 shows that only a small percentage of sediment was transported during non-event as compared to events and that this occurred during a specific time of the year.

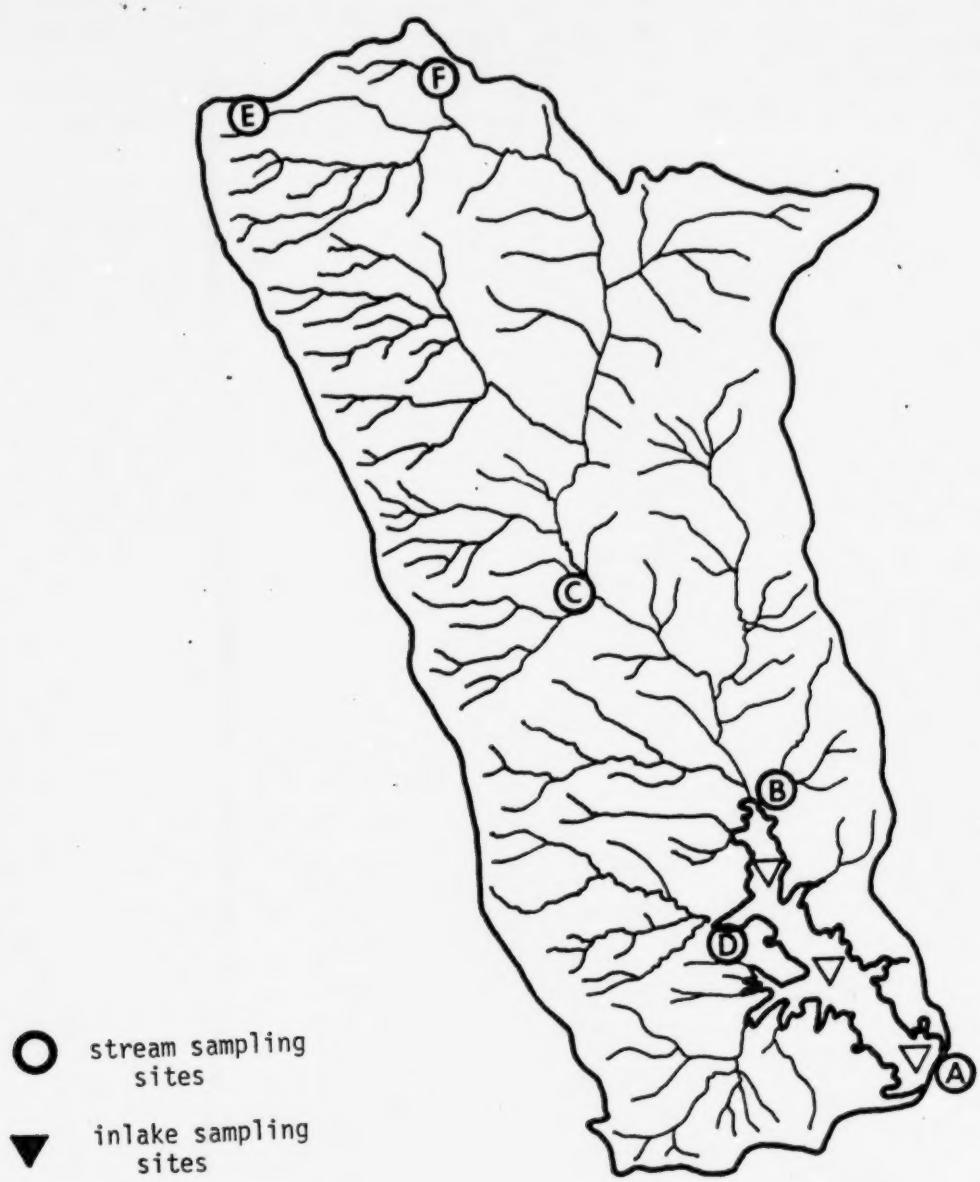
Three periods, based on the amount of surface cover and land management activities were selected for evaluating seasons and variation in total solids transport. These periods were selected to represent the normal agricultural management pattern of the watershed. These periods are:

P1 - fertilizer, seedbed, and establishment period (April-June); P2 - reproduction and maturation period (July-November); and P3 - residue period (December-March). Alberts (1978) used this three season concept to examine seasonal losses of nitrogen and phosphorus in Missouri. There will be some variation in period length from year to year due to climatic variances; in Water Years 1980 and 1981 this variation was significant.

Total suspended solids transport is time variant due to surface cover, precipitation patterns and land management activities (Table 3). During P1 (April-June) there is a high degree of soil disturbance, combined with severe thunderstorms, results in the majority of total suspended solids being transported during this period. During P2 the increased surface cover and infiltration of precipitation appeared to decrease suspended solids transport from cropland. Precipitation during P3 usually occurs as snowfall on frozen ground, that is covered with residue, so suspended solids transport was expected to be minor.

Total suspended solids transport (Table 3) showed a definite "upstream -- downstream" trend with lower quantities measured downstream. At Station C, (Figure 6) about 99% of total suspended solids transport during May through June, 1981 occurred during storm events; during July through September it was 98%. During Water Year 1981, about 98% of the total suspended solids transport occurred during storm events. Station B showed a similar relationship, but the total quantity measured was 26% of Station C's quantity. (Fig. 7) The flow constriction device, a causeway and bridge at Station B, causes differential velocities in storm flow to occur between B and C, thus allowing the suspended matter to settle out in the channel (Davenport, 1982B). The lake area immediately upstream from station B has lost 95% of its sediment storage capacity due to accumulation. For a brief description of the individual monitoring stations see Appendix Section.

Figure 6. Map of Water Quality Stations in the Blue Creek Watershed in Pike County, Illinois



The trap efficiency of a lake is the percent of the sediment entering the lake which is deposited in the lake. The remaining portion of sediment is carried through the lake and on downstream. A reservoir trap efficiency of 93% was predicted from the Brune reservoir trap efficiency curve (Bogner, 1979). Extrapolation of Station B's yield to the entire watershed would estimate 1080 tons of suspended solids was delivered to the lake during May to October (1981). This should be considered as a minimum quantity due to changes and spatial variation in land use/cover on the remainder of the watershed adjacent to the lake. Combining this estimate with what was measured at Station A and what was removed by the water treatment plant (3.3 tons) would indicate nearly 1058 tons of suspended solids (98%) settled out or water remained in suspension within the lake. The data collection for Water Years 1980 and 1981 indicated the reservoir trap efficiency was 98% and 99%; respectively.

Figure 7.

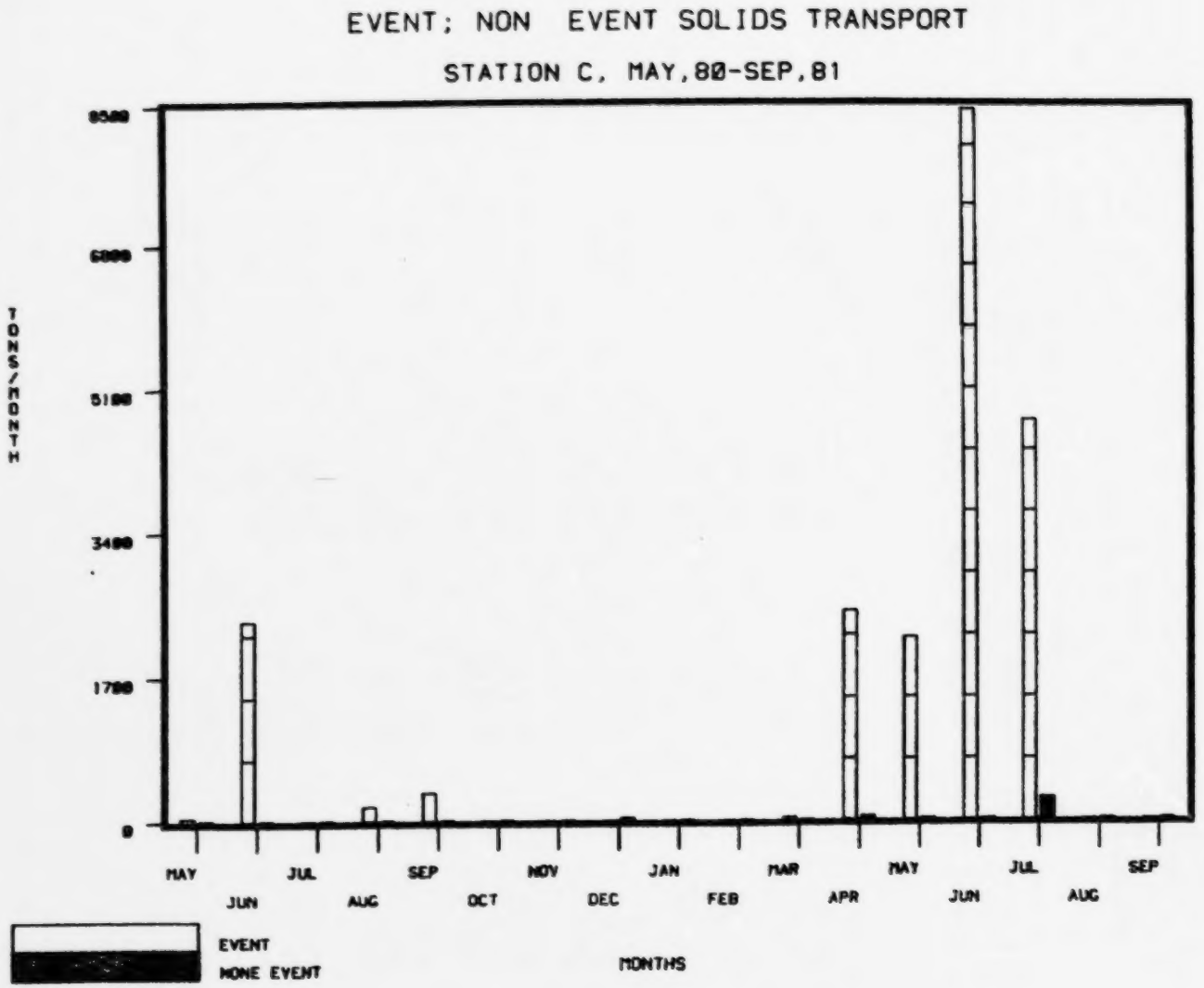

EVENT; NON EVENT SOLIDS TRANSPORT
STATION C, MAY,80-SEP,81
8500
6800
5100
3400
1700
0
TONS/MONTH
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
EVENT
NONE EVENT
MONTHS

Table 3

Total, event and non-event suspended solids transport for each station by Water Year and Analysis Period in tons.

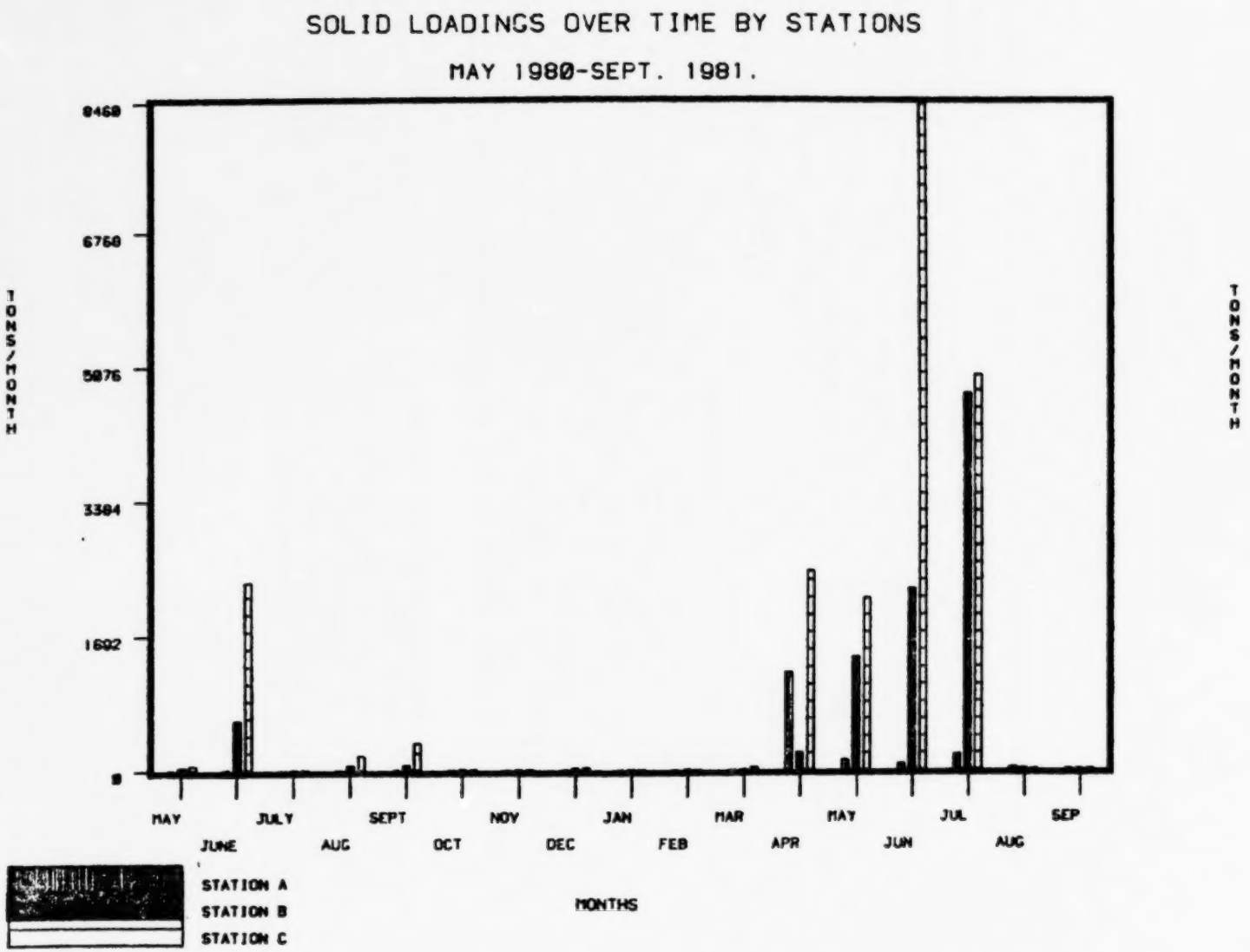
		Station A	Station B	Station C
Water Year 1980*	Total	18.16	464.20	1703.05
	Event	5.66	447.58	1684.84
	Non-Event	12.50	15.62	18.21
Water Year 1981	Total	568.00	8724.00	18,170.00
	Event	128.43	6482.14	17,821.50
	Non-Event	439.57	2241.86	348.50
P1 1980	Total	11.48	397.73	1385.42
	Event	4.52	385.38	1374.94
	Non-Event	6.96	12.35	10.48
P1 1981	Total	316.70	3905.00	13,124.00
	Event	81.85	3839.00	13,065.00
	Non-Event	234.85	66.00	59.00
P2 1980	Total	8.20	73.87	319.69
	Event	1.14	62.20	309.90
	Non-Event	7.06	11.67	9.79
P2 1981	Total	239.00	4755.85	4982.76
	Event	45.30	4044.00	4723.00
	Non-Event	193.70	711.85	259.76
P3 1981	Total	10.68	55.39	63.42
	Event	1.48	2.14	33.50
	Non-Event	9.20	53.25	29.92

*May-September

In this portion of the study, the tons of total suspended solids per acre measured at drainage area B (Figure 4) is calculated to be 1.8 tons/acre (8724 tons/4858 acres). If it is assumed that the remainder of the watershed also has a similar total suspended solids delivery rate, the amount of tons contributing per acre of the watershed is 12,233 tons (1.8 tons per acre x 6810 acres). This is the amount of total suspended solids reaching the lake. It is important to note that this is a minimum value because there is a lack of data on the runoff from the land adjacent to the lake. According to the variable source concept, lands surrounding the lake would deliver a greater amount of total suspended solids when compared to upstream areas within the watershed. Therefore the amount of total suspended solids being deposited in the lake would be higher.

The total amount of gross erosion was determined to be 63,313 tons (62,867 tons by sheet and rill erosion and 446 tons by gully erosion). The lake sedimentation survey of Lake Pittsfield (Bogner, 1979) indicated the

Figure 8.


SOLID LOADINGS OVER TIME BY STATIONS
MAY 1980-SEPT. 1981.
8460
6760
5076
3384
1692
0
TONS/MONTH
TONS/MONTH
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
MONTHS
STATION A
STATION B
STATION C

average annual sediment deposition in the lake for the past 18.3 years (1961-1979) was 38,576 tons. The annual runoff of the Blue Creek Watershed is estimated to be 440 acre feet per year per square mile. With a drainage area of 11 square miles, excluding the lake area, the annual inflow into Lake Pittsfield is 4743 acre-feet (Ming, 1981). The lake sedimentation survey (Bogner, 1979) showed the lake capacity to be 2773 acre feet. Therefore, the capacity - inflow ratio (C/I) becomes 0.585. From the Brune trap efficiency curve, the trap efficiency is estimated to be 93%. Therefore the annual sediment yield of the Blue Creek Watershed is 41,480 tons (38,576/0.93). The delivery ratio, which is the ratio of sediment yield to the amount of gross erosion (41,480/63,313), is calculated to be 66%.

Lee (1981) estimated the sediment delivery ration to be 48% for the Blue Creek Watershed. This is a 38% decrease over that calculated for this study. This difference is due to the large discrepancy in total erosion estimate between the studies. This discrepancy can be attributed to the fact that the land use/cover composition within Lee's study area on which he based his extrapolation, is different from the remainder of the watershed.

An annual rate of reservoir capacity loss nomograph based on only two parameters: 1) the reservoir capacity expressed in inches on the drainage area, and 2) the size of the drainage area in square miles, can be used to estimate annual capacity loss for a particular proposed reservoir. A determination of the accuracy of this nomograph showed that the annual capacity loss determined will not be more than 60% in error in either direction (Stall, 1964). Using this nomograph annual capacity loss was determined to be 2.3% for Pittsfield City Lake. Currently, it is estimated that 1.08% per year of lake capacity is lost to sedimentation. This 53% lower than the loss calculated using Bulletin 51.

Extrapolation of Results

Table 5 summarizes the potential soil erosion estimates under existing, attainable and ultimate conditions as determined by the ADAPT system. The existing condition was defined by SCS personnel as of October 1, 1980. Attainable conditions are those land management conditions associated with the implementation of conservation practices under the ACP - Special Water Quality Project. Ultimate conditions are land management conditions most likely to be there long term. Poth the attainable and ultimate conditions were defined by the local District Conservationist, in the same manner described in the methods section for existing conditions.

Table 5. Acres, average erosion, percent of the total erosion by land use/cover for the three specified management levels. (Gates, 1981)

Land Use/ Crop Type	EXISTING CONDITION			ATTAINABLE CONDITIONS			ULTIMATE CONDITIONS		
	No. of Acres	Erosion (Tons/Acre)	Percent of Total Erosion	No. of Acres	Erosion (Tons/Acre)	Percent of Total Erosion	No. of Acres	Erosion (Tons/Acre)	Percent of Total Erosion
C-S	760.2	26.0	31.47	447.6	9.4	13.68	342.7	5.1	8.41
C-C-S	315.5	22.0	11.05	315.5	8.6	8.28	258.9	7.5	9.38
Continuous Corn	931.7	15.6	23.14	1163.8	9.6	34.34	1117.1	6.8	36.77
C-S-G	129.5	14.4	3.07	217.4	6.9	4.63	238.9	4.4	5.02
C-S-G-M	466.1	8.6	6.40	410.0	4.5	5.70	456.3	2.9	6.28
C-S-G-M-M-M	601.3	7.3	6.96	616.8	4.7	8.83	688.1	2.8	9.26
C-S-G-M-M-M-M	756.3	5.8	6.98	759.7	3.9	9.05	792.2	2.8	10.71
Past/Hay 80% Cover	731.3	1.9	2.24	497.5	2.1	3.14	83.0	1.4	0.55
Past/Hay 95% Cover	788.0	0.3	0.37	1061.7	0.3	1.02	1546.5	0.4	2.73
Woodland-Managed	543.6	0.6	0.49	647.8	0.6	1.15	811.3	0.6	2.30
Woodland-Unmanaged	266.4	8.9	3.77	164.9	8.7	4.4	1.4	3.46	0.02
Wildlife	311.7	0.4	0.14	283.9	0.4	0.33	283.9	0.4	0.52
Farmstead	109.1	1.1	0.14	109.1	1.1	0.36	109.1	1.1	0.57
Feedlot	65.5	35.5	3.70	50.7	32.67	5.08	46.8	33.1	7.41
Water	236.4	0	0	236.4	0	0	236.4	0	0
TOTAL	7012.8	9.0	100	7012.8	4.7	100	7012.8	3.2	

C: Corn; S: Soybean; G: Grain; M: Meadow

Comparison of these scenarios showed several trends. First, there were no major land use shifts between the scenarios and second, there is a substantial decrease in the total erosion (Table 4). These trends indicate that the amount of sediment being deposited in Lake Pittsfield would be reduced because the potential gross erosion is decreased 47.8% from existing to attainable conditions. Under ultimate conditions the potential gross erosion would be reduced by 66% from existing conditions. Clearly, the increase in conservation practices produced a substantial decrease in the total erosion. This has important implications for Lake Pittsfield because a significant decrease in potential gross erosion would decrease the rate at which the lake is filling with sediment, thereby extending its life.

The lake sedimentation survey (Bogner, 1979) determined that 38,576 tons of sediment had been deposited in the lake in 18.3 years. This means that the annual rate of lake capacity lost to sedimentation is 1.08% per year. At this rate, Lake Pittsfield would be completely filled in 92 years. However, under attainable conditions only 21,828.58 tons would be delivered to the lake and 20,300 tons would be deposited in Lake Pittsfield itself. This is a reduction from current conditions of 47%. Under this condition, the rate of depletion of original storage would be reduced to 0.57% per year. Therefore, the life of the lake would be extended to 143 years, a gain of 51 years.

Under ultimate conditions 13,980.98 tons of sediment are transported and 13,002 tons deposited in Lake Pittsfield. The amount of sediment deposition would be reduced by 66%. By implementing long term conservation practices, the annual rate of lake capacity lost to sedimentation is reduced to 0.36% per year, meaning that the life of the lake would be extended 222 years. It should be noted, however, these numbers are only valid if ultimate or attainable conditions are put into practice immediately, and if the sediment delivery ratio and trap efficiency of the lake remains constant. Changes in the sediment delivery ratio are likely due to changes in the sediment source areas. As noted rated earlier, a substantial reduction is the amount of sediment delivered to a stream may result in a compensatory increase in channel erosion. Channel erosion produces sediment that is immediately available to the transport system, whereas sediment from cropland must first get to the stream before it can be transported. Changes in the trap efficiency are likely as sediment accumulates within the lake thereby decreasing lake storage volume and lowering residence time.

Conclusions

1. Potential gross erosion for the Blue Creek Watershed Basin is estimated to be 63,313 tons/year. Sheet and rill erosion contributes 62,867 tons (99%) and gully and streambank contributes 446 tons.

2. The gross erosion rate from the watershed was compared with lake sedimentation data from Pittsfield Lake to determine the sediment delivery ratio. This ratio was calculated to be 66%. This is a 38% increase over that estimated in a previous study.

3. Any reduction in soil erosion due to improved land management practices would lead to a reduction in material delivered to the lake.

4. Currently, 1.08% per year of lake capacity is lost to sedimentation. This is 53% lower than the loss calculated using Bulletin 51. Under these conditions the lake will be completely filled in 92 years. Under attainable conditions the life of the lake would be extended to 143 years, a gain of 51 years. Under ultimate conditions 130 years would be added to the life of the lake, extending it to 222 years.

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Appendix A

SCS Erosion Inventory

Instructions for Phase II Data Collection
(USDA-SCS, 1977)

The field data inventory utilized a standard SCS Phase II Erosion Inventory which provided instructions for collecting streambank and gully erosion information.

The study area was divided into sampling units. Within each sampling unit, two sets of data were collected. Section I of the worksheet contained information on all streams and eroding gullies, ditches, and canals that are not on roadsides or construction sites. Both banks of these channels within the sampling unit were recorded.

A bank segment is defined as a portion of the channel for which all recorded bank items are the same. For each bank segment in the sampling unit, the following information was recorded:

Channel Identification
Bank Side
Bank Segment
Type of Channel
Land Use
Length of Bank Segment

The following information was recorded only if the bank segment was eroding:

Average Eroding Bank Slope Length
Average Annual Recession
Volume Weight

Section II of the worksheet contained information on erosion on construction sites, roads, roadsides, and channel bottoms. Strip mines, gravel pits and other extrative activities are not considered construction sites. The maximum size was one contiguous acre. A separate worksheet was provided for recording the type of eroding material and the method for calculating soil loss. In Section II the Universal Soil Loss Equation (USLE) or the Direct Volume method could be used to compute the annual tons of erosion.

If the USLE method was used, data for the equation A=RKLSCP was entered on the worksheet, where A is the average annual soil loss in tons/acre as predicted by the equation, R is the rainfall and runoff factor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the cover and management factor and P is the support practice factor. For a detailed explanation of the factors in the Universal Soil Loss Equation refer to Universal Soil Loss Equation (United States Department of Agriculture, 1977).

If the Direct Volume method was used, the following information was recorded:

1. Length, in feet, of the bank or road under consideration.
2. Average slop length, to the nearest half-foot, of the eroding portion of the bank.
3. Estimated annual average recession, to the nearest 0.05 foot, of the segment.
4. Average estimated weight per cubic foot, in pounds, for the eroding material.

SCS EROSION INVENTORY--PHASE II WORKSHEET (1978-79)

Affix label here

Technician _____ Date _____

Are there any streams in this PSU? . . . . . Yes ☐ No ☐

Are there any eroding gullies, ditches, or canals in this PSU? . . . Yes ☐ No ☐

Are there any eroding roads or roadsides in this PSU? . . . . . Yes ☐ No ☐

Are there any areas disturbed by construction activity in this PSU? . Yes ☐ No ☐

Sheet ___ of ___

SECTION I: CHANNELBANK WORKSHEET

Channel ID	Bank (L,R)	Bank Segment No.	Type of Channel (S,G,D,X)	Land Use (R,U)	Length of Segment (feet)	Complete only if eroding: Average Eroding Bank Slope Length(ft)	Annual Lateral Recession (feet)	Volume Weight (lbs/ft^3)

Field Sketch

Appendix C

List of Cropping Systems, Tillage Systems, And Conservation Practices Utilized in the ADAPT Field Level Study

Cropping Systems

- Corn -- Soybeans
- Corn -- Corn -- Soybeans
- Continuous Corn
- Corn -- Soybeans -- Grain
- Corn -- Soybeans -- Grain -- Meadow
- Corn -- Soybeans -- Grain -- Meadow -- Meadow -- Meadow
- Corn -- Soybeans -- Grain -- Meadow -- Meadow -- Meadow -- Meadow

Tillage Practices

- Moldboard Plow -- Spring
- Moldboard Plow -- Fall
- Chisel Plow -- 1 -- 2000 lbs. residue
- Chisel Plow -- 2 -- 3000 lbs. residue
- Chisel Plow -- 3 -- 4000 lbs. residue
- No-till -- 1 -- 2000 lbs. residue
- No-till -- 2 -- 3000 lbs. residue
- No-till -- 3 -- 4000 lbs. residue
- No-till -- 4 -- 6000 lbs. residue

Conservation Practices

- No Practice
- Contouring
- Terraces
- Stripcropping
- Pasture Seeding or Critical Area Seeding
- Livestock Exclusion
- Animal Waste System

Appendix D

Stations A & B

Station A, the spillway, samples outflow of the lake. The drainage area is 7,029 acres including the lake.

Station B's drainage area is approximately 70% (4,858 acres) of the Blue Creek Watershed. It is located at the upper end of the lake on Blue Creek, this point characterizes the major lake inflow. Upstream of the causeway at Station B, sedimentation occurs due to the causeway flow restriction and backwater effects.

Station C

Station C, is located at the Highway 107 bridge crossing Blue Creek. The most comprehensive sampling in the project area was conducted at this site. Streamflow is measured at Station C. Sampling frequency is daily, weekly and event related.

This sub-watershed drains approximately 50% (3,339 acres) of the Blue Creek Watershed. Land use by acreage in this sub-watershed is presented in the Table below. In general, the relative proportion of each use is similar to the overall land use in the entire project area. Pasture and cropland comprise nearly 80% of the use with over two-thirds of the total in row crop production. Feedlot acreage is listed both under the woodland and farmstead land use category depending upon the type of operation.

TABLE

Land use by acreage for the sub-watershed drainage area to Station C in the Blue Creek Watershed as of October 1, 1981.

Land Use	Acreage	Percent Total
Cropland	2006	60.0
Pasture/Hayland	768	23.0
Woodland	288	8.6
Wildland	196	5.9
Farmstead	33	1.0
Feedlot	48	1.5
Total	3339	100

TED/ba/sp3433c/1-40